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MATERIAL - HRP - 3/8 OX AND 3/4 OX HEXCEL FOAM FILLED CORE - SHEAR STRENGTH AND SHEAR MODULUS - DETERMINATION OF

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GENERAL DYNAMICS | FORT WORTH

TEST DATA MEMORANDUM

F TDM NO. 3048
MODEL 55
TEST NO. 50-2294

TEST: MATERIAL - HRP - 3/8 OX AND 3/4 OX HEXCEL FOAM FILLED CORE - SHEAR STRENGTH AND SHEAR MODULUS - DETERMINATION OF

OBJECT: To obtain core shear strength and shear modulus of rigidity data on Hexcel's HRP 3/8 OX 3.1 lbs./ft.^{3} and 3/4 OX 2.2 lbs./ft.^{3} core material as foam filled sandwich specimens.

TEST SPECIMENS AND PROCEDURES:
Test specimens and procedures are listed in Table I.

RESULTS:
Results are shown in Table II.

DISCUSSION:
Shear strength and shear modulus data of typical sections of the Centaur Thermal Shroud are needed to evaluate the structural integrity and fabrication processes of the latest design. The purpose of this test was to obtain this information from shop fabricated specimens by testing the specimens in accordance with GD/FW's FZM-2352 (page B-003-1) Specification. The span lengths were specified in the test request as 7" and 14". All specimens were produced by the GD/FW production shop under similiar conditions to production Centaur parts.

Test results for foam-filled core specimens indicate higher shear moduli and core shear results with this light density core material as compared to non-foam filled core specimens. Results of the 1.75" core thickness specimens were according to predictions, but considerable variations were observed in the 0.7" thick core specimens. Apparently the specimen configuration, skin thickness, core thickness and/or span lengths were incompatible with the two span length shear modulus formula (FZM 2352). For example, the calculated shear modulus values for the 3/8 OX "W" ribbon direction are negative values. If several foam filled beams of this thickness (0.7") had been tested as single length beams and the span varied to such an extent to yield a bending factor (FZM 2352, B-003-2, 4 of 4) between .4-.6, the shear modulus would have most probably been reliably accurate and this experimentally determined short span, when doubled would probably fill the requirements for the two span length shear modulus formula. The data listed in Table II was confirmed by a retest of one beam for each of the .7" thick core and appears in Table II.

CONCLUSIONS:
The core shear strength and shear modulus was determined on Hexcel's HRP 3/8 OX 3.1 lbs./ft.^{3} and 3/4 OX 2.2 lbs./ft.^{3} core material as foam filled beams and the data is listed in Table II.

The tests described in this report were performed in the Engineering Materials Laboratory between 9-3-62 to 9-18-62.

WITNESS: BY J. P. Thomas

X CHECKED H. P. Owen

DATE: September 21, 1962 APPROVED K E Ro[illegible]

*See Supplemental Sheets S-1 thru S-5. A. Wilson

TABLE I

TEST SPECIMENS AND TEST PROCEDURES OF FOAM FILLED HEXCEL'S HRP 3/8 OX 3.1 lbs./ft.^{3} AND 3/4 OX 2.2 lbs./ft.^{3} CORE MATERIAL

A. <u>TEST SPECIMENS</u>: Twenty-four specimens were furnished as follows:

NO. SPEC.	RIBBON DIR.	APPROX. SIZE	THICKNESS CORE	TYPE CORE	SOURCE
4	L	3" X 16"	.7"	3/8 OX	GD/FW SHOP
4	W	"	.7	3/8 OX	"
4	L	"	1.75	3/8 OX	"
4	W	"	1.75	3/8 OX	"
4	L	"	.7	3/4 OX	"
4	W	"	.7	3/4 OX	"

B. <u>FABRICATION OF SPECIMENS</u>: The panels were of three types as listed below:

1. Skins, 3 ply 181 FMS-0031 Class III bonded with Narmco 306 adhesive to core (.7" thick) 3/8" OX filled with American Latex 2 lbs./ft.^{3} .602 foam.

2. Skins, 3 ply 181 FMS-0031 Class III bonded with 306 adhesive to core (1.75" thick) 3/8 OX filled with 602 foam.

3. Skins, 3 ply 181 FMS-0031 Class III bonded with 306 adhesive to core (.7" thick) 3/4 OX filled with 602 foam.

C. <u>TESTING OF SPECIMENS</u>: All specimens as described above were tested with loads and load pads as follows:

TYPE	LONG SPAN LOAD	LONG BEAM LOAD RATE IN./MIN.	SHORT BEAM LOAD RATE IN./MIN.	LOAD PADS: LONG SPAN SUPPORT	LOAD PADS: LONG SPAN LOAD	LOAD PADS: SHORT SPAN SUPPORT	LOAD PADS: SHORT SPAN LOAD
1	273	.24	.09	.5"	.75"	1.5"	3"
2	666	.10	.04	.75	1.5	1.25	2.5
3	229	.24	.09	.75	1.5	1.00	2.00

The specimens were tested first using the 14" span and then the 7" span in a Baldwin Universal test machine at room temperature and the slopes recorded. These data were then used to compute the core shear and shear modulus using the formulas per FZM 2352.

TABLE II

CORE SHEAR AND SHEAR MODULUS RESULTS FOR HEXCEL'S HRP 3/8 OX AND 3/4 OX FOAM FILLED CORE MATERIAL.

SPEC. NO.	RIBBON DIRECTION	CORE THICK (IN.)	TYPE	LOAD TO FAILURE (LBS)	P/Δ SHORT SPAN (LBS/IN.)	P/Δ LONG SPAN (LBS/IN.)	SHEAR MOD. (PSI)	CORE SHEAR (PSI)
1.	L	1.75	2	1340	16,234	4,386	7,406	128
2.	L	1.75	2	1265	15,723	4,329	7,011	120
3.	L	1.75	2	1355	16,319	4,367	7,491	129
4.	L	1.75	2	1275	16,055	4,375	7,202	120
	AVERAGE:						7,278	124
5.	W	1.75	2	1955	34,482	7,002	22,185	188
6.	W	1.75	2	2030	32,051	7,225	17,785	195
7.	W	1.75	2	2110	35,714	7,364	22,317	202
8.	W	1.75	2	1865	34,722	7,485	20,272	178
	AVERAGE:						20,640	191
9.	L	.7	1	782	8,000	1,181	29,585	179
10.	L	.7	1	787	8,039	1,168	32,599	180
11.	L	.7	1	793	8,064	1,183	31,113	181
12.	L	.7	1	815	8,196	1,173	36,788	186
	AVERAGE:						32,521	182
13.	W	.7	1	982.	12,821	1,531	-158,818*	226
14.	W	.7	1	998	13,514	1,563	- 93,047*	225
15.	W	.7	1	966	13,158	1,534	-101,534*	218
16.	W	.7	1	979	12,870	1,546	-181,913*	223
	AVERAGE:						-133,828	223

TABLE II (Cont'd)

CORE SHEAR AND SHEAR MODULUS RESULTS FOR HEXCEL'S HRP 3/8 OX AND 3/4 OX FOAM FILLED CORE MATERIAL.

SPEC. NO.	RIBBON DIRECTION	CORE THICK. (IN.)	TYPE	LOAD TO FAILURE (LBS)	P/Δ SHORT SPAN (LBS/IN.)	P/Δ LONG SPAN (LBS/IN.)	SHEAR MOD. (PSI)	CORE SHEAR (PSI)
17.	L	.7	3	513	4,790	1,000	6,747	117
18.	L	.7	3	527	4,941	1,003	7,281	120
19.	L	.7	3	520	4,831	1,018	6,671	117
20.	L	.7	3	498	4,854	984	7,096	112
AVERAGE:							6,948	117
21.	W	.7	3	815	9,524	1,471	28,146	185
22.	W	.7	3	895	9,823	1,511	29,379	202
23.	W	.7	3	830	10,000	1,492	34,507	187
24.	W	.7	3	841	9,398	1,486	25,027	189
AVERAGE:							29,265	191
				RETEST VALUES				
25.	L	.7	1	827	8,237	1,244	27,088	189
26.	W	.7	1	1100	12,919	1,563	-214,586*	226
27.	L	.7	3	539	4,651	1,037	5,968	122
28.	W	.7	3	864	9,728	1,555	25,287	197

NOTE: Shear moduli values for the 0.7" thick core specimens are questionable because specimen configuration and test span lengths are not compatible with the 2-span length formula specified in FZM-2352. *Note negative values for Type I specimens. In this test it appears that core shear data is consistent and reproducible and would be considerably more reliable in determining the foam filled core strength than the shear modulus.

Method B-003-1

SANDWICH TWO SPAN LENGTH

SHEAR BEAM TEST

SCOPE: This method is designed for use in determing the core shear modulus and shear strength of flat sandwich beams by use of a flexural two span length test. This method is recommended as being the most accurate for the determination of core shear modulus.

TEST SPECIMEN:

A. The general test specimen configuration shall be as given on the introductory page to this method.

B. The core thickness, "t_c", recommended for this test is usually 0.450 to 0.750 inches. A core thickness tolerance of $\pm$ 0.005 inches is recommended. If possible, a tolerance of $\pm$ 0.003 inches should be used.

C. The specimen width, "B", should be not less than twice the specimen thickness, "t". (B 2t) B = 3 inches is usually selected.

D. The short span length, "L_2", for test should be not less than twice the specimen length, "B". (L_2 2B) $L_2 = 6$ inches is usually selected.

E. The long span length, "L_1", for test should be exactly twice the short span length, "L_2". ($L_1 = 2L_2$) $L_1 = 12$ inches when L_2 - 6 inches.

F. The specimen length, "S", should be two inches longer than the long span. "L_1", to allow one inch overhangs beyond the support points of the test jig. When $L_2 = 6$ inches and L_1 - 12 inches, S = 14 in.

G. The sandwich face thicknesses, "t_f", should be the standard thickness which is closest to the value calculated below:

$$t_f = \frac{L_2^{\,2} G_c (1 - \;^2)}{6\, t_c E_f}, \text{ inches} \qquad (1)$$

G_c must either be taken from previous data or it must be estimated, for the particular temperature of test. Clad aluminum alloy faces are usually selected for this test for temperatures below 300°F. Some values of E_f and are as follows:

Aluminum Alloy Faces		E_f @ R.T.	E_f @ 260°F
Clad 7075-T6	0.33	10.4×10^6 psi	9.2×10^6 psi
Clad 2024-T86	0.34	10.6×10^6 psi	9.5×10^6 psi

Test Specimen (Cont'd.)

G. (Cont'd.)

If reinforced plastic faces are used the values of " " and "E_f" must be estimated from reported data. Because of variations of " " and "E_f" within a particular laminate, reinforced plastics are not recommended for sandwich faces in a shear modulus test.

H. The face stress in the sandwich specimen during test should never exceed 80% of yield strength. This should be calculated for both the long and short span, as follows:

$$f_f = \frac{P_1 L_1}{2Bt_f(t + t_c)} \quad 0.80\ (F_y),\ \text{psi} \qquad (2)$$

$$f_f = \frac{F_{su} L_2}{2t_f} \quad 0.80\ (F_y),\ \text{psi} \qquad (3)$$

P_1 is the maximum load for the long span, as calculated in the test procedure. F_{su} must either be taken from previous data or it must be estimated, for the particular temperature of test. The value of F_y for the faces must also be estimated or obtained from data. If either of the two alloys mentioned in (G) on the previous page are used as the faces, a value of F_y = 60,000 psi will be satisfactory for test temperatures below 300°F. If the calculations above show that 80% F_y will be exceeded,thicker faces must be used on the sandwich specimen.

I. Measure the exact core thickness, "t_c", and face thicknesses, "t_f". Then bond the sandwich panel together using a suitable adhesive between each face and the core. A suitable adhesive is any adhesive that will prevent an initial bond failure during test. A specific adhesive may be specified in the applicable test document.

J. Cut the desired number of test specimens from the resulting sandwich panel and measure the exact width, "B", and thickness "t", of each specimen.

<u>TEST PROCEDURE</u>: (Equal thickness sandwich faces of the same material)

A. Two flexural test jigs are required for this test, one with a span of "L_1" and the other with a span of "L_2", as calculated in (D) and (E)on the previous page. The test is to be performed in a single point load set-up as shown on the introductory pages to this method.

TEST PROCEDURES: (Cont'd.)

B. To prevent core crushing under the load and reaction points, it will be necessary to provide bearing plates. The bearing plate area in contact with the specimen must be large enough to prevent the compressive stress, at any time during the test, from exceeding 80% of F_{cu}. The necessary bearing plate area should be calculated as follows:

Long Span (L_1)
(each reaction point)

$$A = \frac{P_1}{(2)(0.80)(F_{cu})}, \text{ (inches)}^2 \qquad (4)$$

(load point)

$$A = \frac{P_1}{(0.80)(F_{cu})}, \text{ (inches)}^2 \qquad (5)$$

Short Span (L_2)
(each reaction point)

$$A = \frac{F_{su}B(t + t_c)}{(2)(0.80)(F_{cu})}, \text{ (inches)}^2 \qquad (6)$$

(load point)

$$A = \frac{F_{su}B(t + tc)}{(0.80)(F_{cu})}, \text{ (inches)}^2 \qquad (7)$$

P_1 is the maximum load for the long span. F_{su} and F_{cu} must either be taken from previous data or they must be estimated, for the particular temperature of test. The bearing plate width, necessary to give the required area, "A", should be rounded off, upwards, to the nearest 0.25 inch increment so that standard size bearing plates can be used.

C. Position the specimen on the long span (L_1) test jig so that there is a one inch overhang beyond each support point. Bring the loading heat of the machine down to contact the specimen at the center of the span and adjust the extensometer probe, supported on the test jig base, so that it contacts the underside of the specimen directly below the load point.

TEST PROCEDURE: (Cont'd.)

D. Load the specimen to the maximum load "P_1" at a constant deflection rate, "H_1", as monitored by a strain pacer. During the test a load vs. deflection graph is to be recorded autographically using a deflection magnification such that the curve will have an approximate 45^o slope. Release the load immediately after "P_1" has been reached. Calculate "P_1" and "H_1" as follows:

$$P_1 = B(0.60)\,(F_{su})(t + t_c), \text{ pounds} \tag{8}$$

$$H_1 = \frac{ZL_1^{\,2}(1.25)}{6t}, \text{ inches per minute} \tag{9}$$

Z = 0.0015 inches per inch per minute for aluminum faces
Z = 0.0005 inches per inch per minute for steel faces
Z = 0.0045 inches per inch per minute for reinforced plastic faces.

F_{su} must either be taken from previous data or must be estimated for the particular temperature of test.

E. Repeat step (C) except that the span length and the deflection rate is to be changed. Also, this time the specimen is to be loaded completely to failure. The specimen is to be positioned on the short span (L_2) test jig so that there are equal overhangs beyond each support point. The specimen is to be loaded to failure at a constant deflection rate of "H_2", as calculated below. Record the failing load and record the load vs. deflection curve as in step (D).

$$H_2 = \frac{ZL_2^{\,2}(2.00)}{6t}, \text{ inches per minute} \tag{10}$$

The "Z" values are the same as for step (D).

TEST PROCEDURE: (Cont'd.)

F. Examine the specimen for acceptable type fo failure according to the introductory pages of this method. Calculate core ultimate shear strength and core shear modulus of rigidity as follows:

$$F_{su} = \frac{P_u}{B(t + t_c)} \text{ psi} \qquad (11)$$

$$G_c = \frac{3L_1 t_c (P/\ \ )_2}{4Bd^2(8 - R)} \text{ psi} \qquad (12)$$

$$R = (P/\ \ )_2/(P/\ \ )_1 \qquad (13)$$

SYMBOLS:

F_{su} = Ultimate core shear strength, (psi)
G_c = Core shear modulus of rigidity, (psi)
P = Applied load at any time during test (lbs)
P_1 = Maximum load for long span (lbs)
P_u = Applied failing load for short span (lbs)
L_1 = Long span length (in)
L_2 = Short span length (in)
$(P/\ \ )_1$ = initial straight line slope of the long span load vs. deflection curve (lbs/in)
$(P/\ \ )_2$ = Initial straight line slope of the short span load vs.deflection curve (lbs/in)
S = Specimen length (in)
B = Specimen width (in)
t = Specimen thickness (in)
t_c = Core thickness (in)
t_f = Sandwich face thickness (in)
A = Bearing plate area in contact with the specimen $(in)^2$
H = Constant deflection rate (in/min)
Z = Sandwich face strain rate (in/in/min)
d = Distance between the centroids of the sandwich specimen faces (in) = $(t + t_c)/2$
= Poisson's ratio of the sandwich face material
E_f = Modulus of elasticity of the sandwich face material (psi)
f_f = Stress in the sandwich faces (psi)
F_y = Yield strength of the sandwich face material (psi)

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